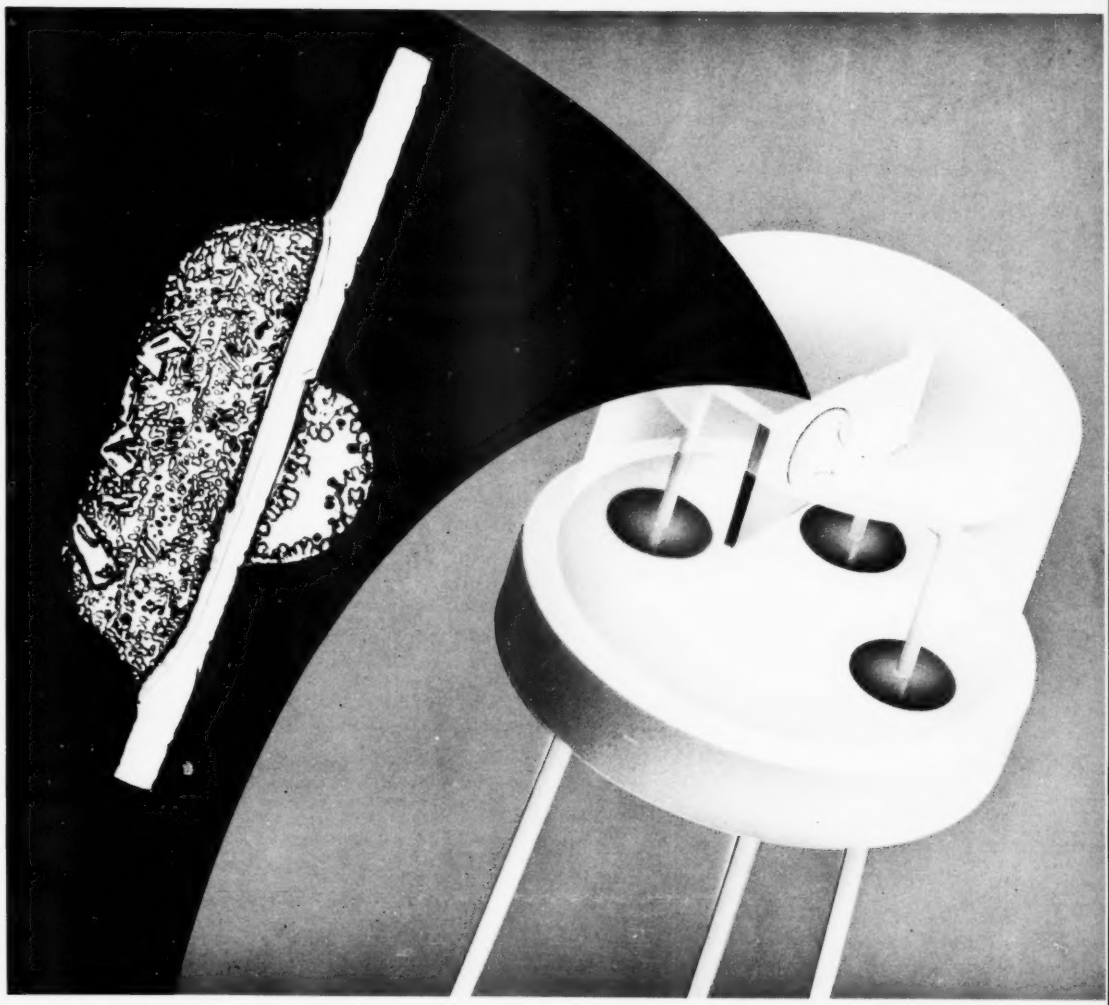
RAYTHEON

ELECTRONIC PROGRESS

MAY
JUNE 1957



A Fusion-Alloy Transistor

In this issue: **TRANSISTORS**

ELECTRONIC PROGRESS

VOLUME 1 **MAY - JUNE 1957** **NUMBER 6**

RAYTHEON

ELECTRONIC PROGRESS

I. A. Getting ..... *Executive Editor*
J. Sterling ..... *Managing Editor*
M. Keilson ..... *Editor*

ASSOCIATE EDITORS

S. D. Crane
Santa Barbara Laboratory

J. H. Day
Commercial Equipment Division

R. D. Eames
Government Equipment Division

A. S. Luftman
Microwave and Power Tube Operations

L. G. Rubin
Research Division

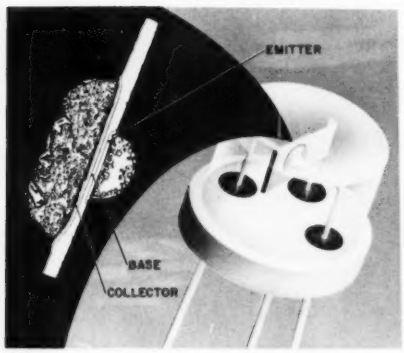
P. Sullivan
Semiconductor Division

M. A. Walker
Missile Systems Division

R. Wood
Receiving and Cathode Ray Tube Operations

Copyright 1957
Raytheon Manufacturing Company
Waltham 54, Mass.

THE COVER



A cross-section of a typical fusion-alloy silicon transistor is shown on our cover. The photomicrograph, taken at a magnification of 120X, shows emitter, base and collector regions with unusual clarity; the same section can also be seen presented to scale within a regulation package. Of the many transistor types made, this, the fusion-alloy, is the most common, nearly seven million having been made by Raytheon to date.

Index

Semiconductor Surfaces	**G. deMars**	**1**
Transistors	**G. Freedman**	**4**
Elements of Analog Computation	**A. N. Nicol and H. A. Miller**	**11**
Technical Publications	**W. W. Drake, Jr.**	**14**
Publications & Papers		**16**
In the Way of a Request		**17**

Calendar

Technical Committee Meetings

	Place	*Time and Date*
Plastics	**Varies**	**As required**
Ferrite	**Varies**	**1st Wed. of the month at 3:00 P.M.**
Semiconductor Devices Circuit	**Wayland Lab**	**May 6 at 2:00 P.M.**
Welding	**Commercial Engineering**	**1st Thurs. of the month at 3:00 P.M.**
Magnetic Amplifier (Mag. Amp. Versus Transistors)	**Wayland Lab**	**May 7, 1957**
Engineering and Scientific Co-ordinating Committee for Digital Computers	**Research**	**As required**

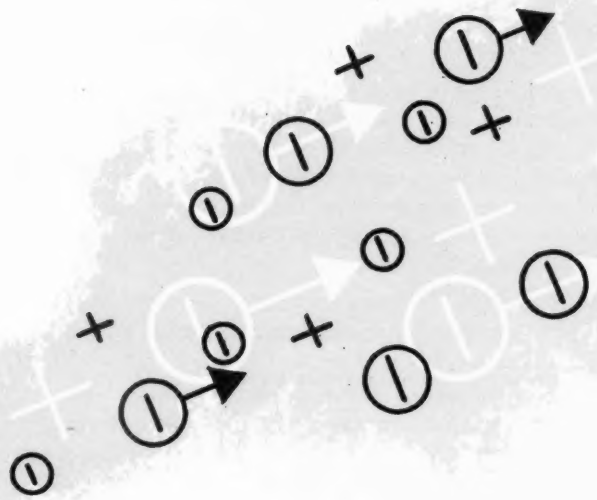
Other Seminars and Courses

	Place	*Time and Date*
Space Charge Seminar	**Research**	**As required**
Ceramics Seminar	**Research**	**Last Tues. of month**

Technical and engineering personnel who desire further information concerning the above calendar should contact Mr. James Sterling, Research Division, Extension 2187.

Semiconductor Surfaces

GEORGE DE MARS
Research Division



PRODUCTION techniques of semiconductor devices have advanced to a point where it is feasible to develop a device to have certain specialized characteristics. That is, using semiconductor theory, one can design a device and be reasonably certain that the specifications as to semiconductor purity and geometry will be met. However, it has often happened that a device has failed to exhibit the desired characteristics not because design specifications were inadequate or unfulfilled, but rather because of the effect of semiconductor surface behavior.

Much of the work which led to the discovery of transistor action was concerned with surface effects on semiconductor rectifying properties. In 1947, Bardeen suggested that electronic states or charged sites on the semiconductor surface could account for the then puzzling observed behavior of semiconductor-metal contacts. After this, Brattain and Shockley found experimental evidence for surface states from contact potential measurements on semiconductors. Later, Shockley showed that the modulation of the conductance of a semiconductor sample by a transverse electric field was much less than expected and explained the results in terms of surface states.

In the years that followed, practically all semiconductor research and engineering was concerned with bulk properties. However, here and there projects were undertaken to investigate surface behavior, and with time their number increased, until today there are many groups engaged in surface studies. These surface studies have confirmed the existence of Bardeen's surface states, taught us much of their structure, and demonstrated their effects on the operating characteristics of devices.

Semiconductor conductance characteristics follow from the behavior of mobile charged carriers (holes and electrons), whose relative densities in the material are controlled by doping the semiconductor with small amounts of impurities. The effect of a negative surface charge on the carrier density of n-type material near the surface is indicated in Figure 1. Here electrons are pushed away from the surface, exposing a space charge layer of immobile, positively charged donor atoms which tend to neutralize the surface charge. If the surface charge density is quite high, then it is also necessary for holes to be drawn to the surface to preserve neutrality, and a conducting p-type surface layer or "inversion" layer is produced. In a similar manner, positive charges on p-type material can produce an n-type surface inversion layer. This modulation of carrier density at the surface by charges in surface states would indicate that surface states affect device operation.

A transistor is essentially an interacting combination of two diodes in one piece of semiconducting material, so that it might be appropriate to consider

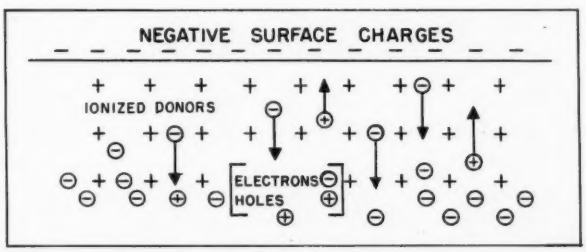


Figure 1 The effect of negative surface charge on an n-type semiconductor.

first the effect of surface conduction on diode characteristics. To make a diode operative, it must be chemically etched so that all conducting surface contaminants are removed. However, even a carefully cleaned and etched diode may not exhibit the expected voltage, current and capacitance characteristics. For example, when examining the operating characteristics of reverse biased diodes, the following have been observed:

1. The reverse current may be a saturation current but is much higher than that predicted by the bulk properties.

2. The reverse current may increase slowly with reverse voltage and/or may creep when the voltage is held constant. In addition, the diode capacitance may be higher than that expected from the bulk properties.

3. The reverse current may show a linear increase with voltage at voltages well below the breakdown voltage.

Let us consider the first case, where the saturation current is high. This saturation current arises from the diffusion of minority carriers across the junction (i.e., electrons diffusing into the p-type material and holes diffusing into the n-type material). The magnitude of this diffusion current, per unit area, is dependent on a number of factors, one of which is recombination lifetime.

It is a property of semiconductors that if a number of minority carriers in excess of the equilibrium number are somehow placed in the material, this excess number will immediately start to diminish through the process of recombining with majority carriers and will continue to diminish in an exponential manner until equilibrium is restored. Thus, the current of minority carriers diffusing across the junction will die out exponentially as it leaves the junction area. The exponential decay can be represented by a time constant called the recombination lifetime. The smaller this lifetime, the greater will be the gradient in the number of excess minority carriers as a function of distance away from the junction, and since the diffusion current is proportional to this gradient, we see that short lifetimes lead to high saturation currents.

To bring the surface condition into the picture, it is now necessary to point out that an effective recombination lifetime results from recombination in the bulk and *at the surface*. The relative contribution of each will depend on the geometry, in particular on the surface-to-volume ratio, of the specimen. The effect of surface recombination becomes more important as the surface-to-volume ratio increases and, since this ratio becomes larger as the overall size of a device diminishes, the very fact that semiconductor devices are so small makes them surface-sensitive. The bulk recombination will be fixed for any given material, but surface recombination may vary greatly with the condition of the particular surface. The surface can be characterized in this respect by a parameter called the surface recombination velocity, which is the ratio of the number of carriers per unit area per unit time

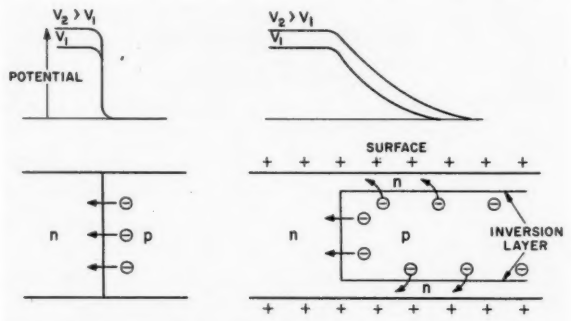


Figure 2 Effect of inversion layer on voltage drop across p-n junction.

recombining at the surface to the number per unit volume available just beneath the surface. Thus, a high surface recombination velocity corresponds to a low value of surface lifetime. On germanium, a rough or strained surface, such as would be produced by sandblasting or grinding, will have a high surface velocity (up to 10^4 cm/sec.), whereas the surface velocity will be quite low (50-200 cm/sec.) on the surface resulting from chemical etching.

The second phenomenon, the observed slow increase in reverse diode current with voltage, may be due to the formation of a surface inversion layer. This surface inversion layer, of course, forms a junction with the bulk material and thus extends the area of the original junction. This added junction is effective as a collector of carriers only in that region where there is a voltage drop across it. Normally, the voltage drop on a reverse-biased diode is confined to a very narrow region at the junction, but with an inversion layer or "channel" present, this drop is spread out, depending on the conductance and current in the channel. (See Figure 2.) This effective added junction area will vary with applied voltage, and so the diode reverse current will vary with voltage. Of course, as the effective junction area increases, so does the diode capacitance.

As stated earlier, the inversion layer results from charges residing on the surface. Now it turns out that there are two places that this surface charge

can appear: first at the interface between the semiconductor and semiconductor oxide film, which forms after chemical or electrolytic etching, and second, on or in the oxide. (See Figure 3.) The charges in these positions or sites are electronically in communication with the bulk material. The occupancy of the interface positions reaches equilibrium in a matter of microseconds, whereas that of the oxide positions may take some minutes to come to equilibrium, which accounts for the observed drift in current following the application of, or a change in, bias voltage.

The charge residing in or on the oxide film is often produced by adsorbed gas molecules which lose or gain charge. The gases which are most likely to affect devices are oxygen, which produces a negative surface charge, and water vapor, which produces a positive charge. Now, if a diode is exposed to a high humidity ambient, many layers of water molecules may sit on the surface. The adsorbed molecules will cause inversion layer formation, as we have seen, and also the outer layers may enter into the picture. When a number of layers of liquid vapor molecules are present, so as to form a coherent film, electronic conduction may occur in that film. The term "electronic conduction," such as occurs in metals or semiconductors, is specified here to differentiate from ionic conduction, such as occurs in electrolytes. This liquid film conduction can account for the observed ohmic behavior of diodes at higher voltages. Liquid film conduction is by no means limited to water vapor, but also has been observed with methyl alcohol, acetone and dioxane.

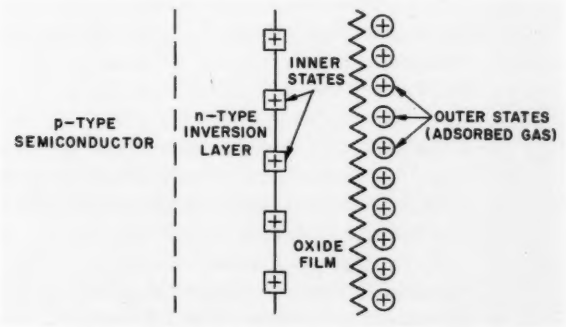


Figure 3 Positions of semiconductor surface states.

The effect of surface behavior on transistor operation can best be illustrated by considering a simple grown junction device. (See Figure 4.) Of course, most devices have a more complex geometry, but the principles will still apply. Here is an n-p-n unit with a grounded base. The first junction, biased in the forward (low impedance) direction, emits electrons into the base region, where they become

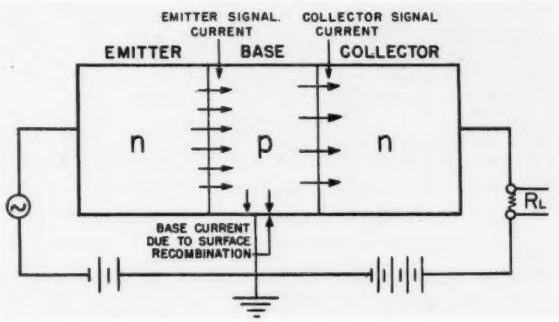


Figure 4 n-p-n transistor (grounded base).

minority carriers. After traversing the base region, most of these electrons are collected at the second junction, biased in the reverse (high impedance) direction. This process whereby a current, which can be modulated, enters the base region through a low impedance and leaves substantially undiminished through a high impedance, makes the transistor a power amplifier. For good power amplification, one would like to have a high efficiency of emission and collection and as few carriers as possible lost while traversing the base region. The surface lifetime in the base region can be quite important here. High surface velocities in this region will raise the collector saturation current and, as shown in Figure 4, lower the percentage of emitted carriers that successfully traverse the base region. For this unit, a high surface velocity means a low α (the ratio of the collector to the emitter signal current); for a grounded emitter unit, which is a current amplifier, the result is a low β (the ratio of the collector signal current to the base signal current). An effective inversion layer (i.e., that portion where there is enough voltage drop to collect carriers) will also increase the collector saturation current and the collector capacitance. Of course, if an effective inversion layer should extend all the way from the collector to the emitter, the transistor action would be diminished to a degree depending on the magnitude of the channel resistance, which may vary greatly. In this respect, a conducting liquid film would be even more disastrous. Another factor influenced by surface behavior is noise, which, in general, is much greater when channels and conducting films are present. However, at the moment, the exact nature of surface noise is not well understood.

In the Research Division, semiconductor surface behavior has been studied for a number of years. Many approaches are used to carry out this study. One important method is that of following changes in surface structure by measurements of weight

changes of a sample. A typical cycle of sample treatment included cleaning of a chemically etched surface by positive ion bombardment, annealing, and controlled oxidation. This technique provides information about the oxidation process and other adsorption mechanisms. Surface adsorption has also been studied using the radio-active tracer technique.

Another method of studying surface behavior is that of measuring the conductance of surface inversion layers and liquid films. These measurements are made on germanium and silicon samples which are essentially grown junction transistors with very wide base regions. These samples are chemically etched and exposed to various gaseous ambients such as ozone, oxygen, water vapor, and ammonia. The surface conductance of the base region due to the channel formed between the emitter and collector is measured as the reverse bias applied to the junctions is varied. (See Figure 5.) The analysis of such conductance data has given much information as to the nature, position and number of surface states. It was found, for instance, that the number of surface recombination states increases with oxidation, and this is borne out by the observed increase in collector saturation current after such treatment. In another instance, some completed transistors had unsatisfactory characteristics believed to be due to inversion layer formation resulting from the presence of oxygen. When these units were exposed to ammonia, they showed a marked improvement, which confirmed the diagnosis and, more important, indicated that the units were suffering from faulty sealing.

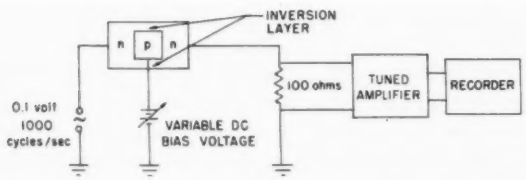


Figure 5. Circuit used for measurement of semiconductor surface conductance.

The continued study of semiconductor surface behavior is desirable if the demonstrably surface-sensitive devices are to exhibit optimum characteristics. For future device designs and uses, particularly at higher temperatures, more knowledge of surface phenomena is indicated. Silicon devices, for instance, should in general perform quite well up to temperatures of 250°C, but are at present limited to a range below 200°C by surface instability. An understanding of semiconductor surface phenomena is important, not only for device development, but also as an aid in determining surface properties of all solid state materials.

Transistors

THE most glamorous of all electrical circuit components these days is, of course, the transistor. It is well known that within five years this device will completely replace more prosaic items such as resistors, condensers, transformers, magnetrons, woofers, tweeters, and on-off switches. As for radio tubes — they are doomed. But don't worry fellows. We'll find a spot for you *someplace* in the organization.

The most important thing to realize about transistor manufacturing is that transistors are not made, they are born. This, of course should make transistors more lovable; and, as everyone knows who has worked with them, they are.

Transistors are born in the sense that they can come out of hot cauldrons of molten metal in almost useable condition. You can grow a transistor like you grow rock candy. You can breathe life into a piece of transistor metal by judicious application of heat and gas. Most other manufactured products are not like this. You don't crystallize a radar set out of a crucible of molten iron and copper. You don't pass bars of steel through a conveyor furnace and have sewing machines emerge at the end. But that is how you make the functioning portions of transistors.

Transistors are made by arranging atoms in configurations predetermined by a combination of (a) nature and (b) people. Factor "b" is somewhat limited by factor "a." If the "people" had their way, the available kinds of atoms one finds in the periodic table of elements would be considerably extended from their present, almost marginal, usefulness to include elements more amenable to manufacture into transistors.

For example, it would be much easier to make transistors out of a material (not germanium or silicon by any means!) which would have the following properties:

It would be as easy to cut as soft iron.

It would be in column 4 of the periodic table and a semiconductor.

It would melt around where aluminum does.

It would be easy to solder to.

It wouldn't corrode.

It wouldn't acquire an oxide film.

G. FREEDMAN
Receiving and Cathode Ray Tube Operations

It would be inexpensive.

It would be easy to purify.

And numerous other things.

While we're at it, for aesthetic reasons, we may as well ask for it to be green throughout.

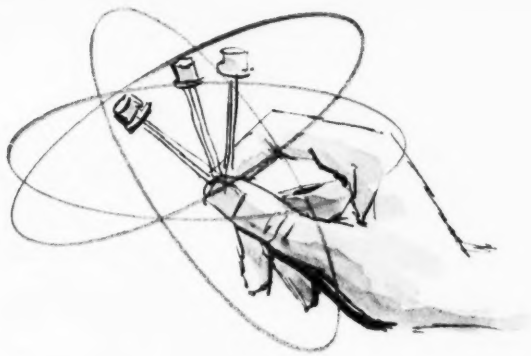
Also, it would be nice to fool around with columns 3 and 5 of the periodic table at the same time. If I had my way, phosphorus and arsenic would be banished to Siberia and aluminum would be allowed to stick around only if it promised many fundamental changes in its character.

But since appeal even to high company executives has not resulted in modification, let alone repeal, of Mendeleev's table, we must resign ourselves to making transistors out of germanium or silicon with admixtures of arsenic, antimony, phosphorus, bismuth, indium, gallium, or aluminum. This is, without a doubt, as motley a collection of chemical elements as ever were mentioned in the same breath. But there they are. That's all there is and all there ever will be. (I think.) If you make transistors — that's your universe. You're limited — it's like making brass. There's very little chance of your making much brass unless you use a great deal of copper and zinc.

On the other hand, look at the advantages. For one — vacuum. It's right there — between all those atoms. It's the best quality vacuum you can get most anywhere, and you don't have to pump to get it.

For another — no filament. You don't have to build a little electric furnace into each transistor before electrons will come out of the emitter (cathode). You get carriers of electricity at human body heat. (Of course this advantage is only relative: If human bodies glowed normally with a cheerful cherry red at 750°C, then cathodes in tubes would be at "room temperature," and to make transistors work we'd need to build a small refrigerator into each!)

If you have been sufficiently benumbed by this deeply philosophical discourse, you are now directed to the more dignified and, I hope, more useful words which follow.



A TRANSISTOR is a device which achieves electrical power amplification when a signal and suitable biases are applied to its three major constructional elements. A triode radio tube may be defined similarly. There are many other analogies between tubes and transistors; however, in one respect, differences are great. This is in the area of diversity of manufacturing techniques.

As far as commonly known, there is only one way to make ordinary tubes (I exclude unusual special types such as magnetrons, klystrons, gas tubes, etc.). There was one way at the beginning and there is one way now. The wound grids, the getter, the vacuum, the aging process, the glass sealing technique — these are essentially the same now as they were when Raytheon moved to Chapel Street from Kendall Square. However, for transistors, an industry barely four years old, there are at least half a dozen different major techniques in commercial use today — and one can think of two or three additional that had their day and are already extinct!

Clearly, this is a shakedown period for transistor manufacturing methods — but on the other hand, it is unlikely that only one method will survive. The product resulting from each manufacturing scheme takes on a definite personality with individual good and bad points. Thus, one is presented with a more subtle and diverse situation in selecting a transistor for use in a given circuit than in selecting a tube — or perhaps just a more confusing one.

Whichever way you put it, whether you try to take advantage of the diversity or try to dispel the confusion, it is important that you understand the

techniques of transistor construction and how these influence electrical performance.

Before going into differences, let us define common ground for junction transistors. No matter how they are made, they all conform to the schematic of Figure 1.

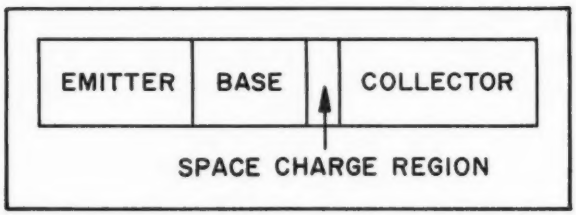


Figure 1. JUNCTION TRANSISTOR

The zones take up their separate characters due to the presence of alloyed-in impurities. N-type impurities (from volumn V of the periodic table) contribute one negative carrier of electricity per atom. P-Type (column III) contribute one positive carrier (a "hole") per atom.

The emitter injects current carriers into the base, most of which drift across this region to be absorbed by the collector. The analogous situation occurs in the tube where electrons are injected into the vacuum region adjacent to the cathode and move through the grid to the plate where they are absorbed or collected. Transistor amplification occurs essentially because the single current level sees a low resistance between emitter and base (the input), and a resistance many orders of magnitude higher between base and collector (the output).

A tube is characterized by a number of mathematical definitions such as G_m, R_p and μ. A transistor is characterized by similar definitions. Different values appear in tube characteristic descriptions as designs are changed — that is, cathode, grids, and plates are changed in relative size and are moved in space in relation to each other. They are then held rigidly in a given orientation by micas. For transistors, similar modifications of characteristics also occur as spacings are changed; but these changes are in terms of layers of atoms grown or frozen over other layers of atoms. These layers are different from tube elements in several ways. One is that the grid equivalent — the base — is three dimensional while tube grids are essentially perforated planes. This additional dimension results in one more degree of freedom with consequent possibility of electrical performance variation.

Like tubes, transistors may be represented by equivalent resistance-capacitance circuits. It is the values in these networks that enter into the mathematical definitions and that are modified by constructional techniques. Some of the more important parameters will be discussed here.

The current amplification factor, α, is a measure of how many carriers of electricity can go from the emitter across the base to be collected by the collector. The fraction of current which does not reach the collector will cause a base current to flow. The base current level may be said roughly to correspond to loss in amplification. Another way of saying this is that, for the situation where the emitter is used as the common terminal, less input power will be consumed for smaller base current.

Carriers are lost as base current if the base region is too wide since these carriers have only a finite lifetime. They are also in effect "lost" if carriers of the opposite sign move across the emitter junction in the opposite direction. Some of this "opposite" conduction will always occur and can be kept down only if the emitter efficiency is high. This is mainly a function of the ratio, γ, emitter conductivity/base conductivity, which in turn depends on the ratio of impurity concentrations in emitter and base. When γ is high, for a small basewidth, α is high.

A capacitance, C_c, exists between collector and base. As one might expect, high frequency performance is improved when this capacitance is low. It is there because the junction consists (if we oversimplify) of a zone, the space charge region, where all carriers (being mobile) are electronically swept out by applied collector-base voltage and only the fixed charges, (ionized, immobile, impurity atoms) remain. This space charge region, a locality where carriers of electricity are absent, therefore has a certain dielectric constant and all the properties of a capacitor.

As in all capacitors, the capacitance is high if the dielectric region is thin and if its area is large. Space charge thickness is a function of the extent of the region around the junction wherein the two impurity types tend to cancel each other. In a diffuse junction, C_c is low; in an abrupt junction,

A Silicon and a Germanium Crystal.

C_c for the same area is high. Differences of as much as three to one may be expected at low voltage. As the name implies, space charge width also varies with voltage. Increasing dc collector-base reverse voltage pulls charge carriers statically to regions of opposite polarity. This tends to deplete the region adjacent to the space charge region of carriers of electricity, effectively increasing its width and decreasing C_c. At the same time, the voltage can cause this space charge widening to extend across an entire base region, causing the phenomenon of collector-to-emitter "punchthrough," V_p. A variable here is impurity content in the base region. Each impurity atom constitutes a fixed charge. If there are relatively many such charges, a given widening of the space region requires relatively more voltage (to overcome the charge).

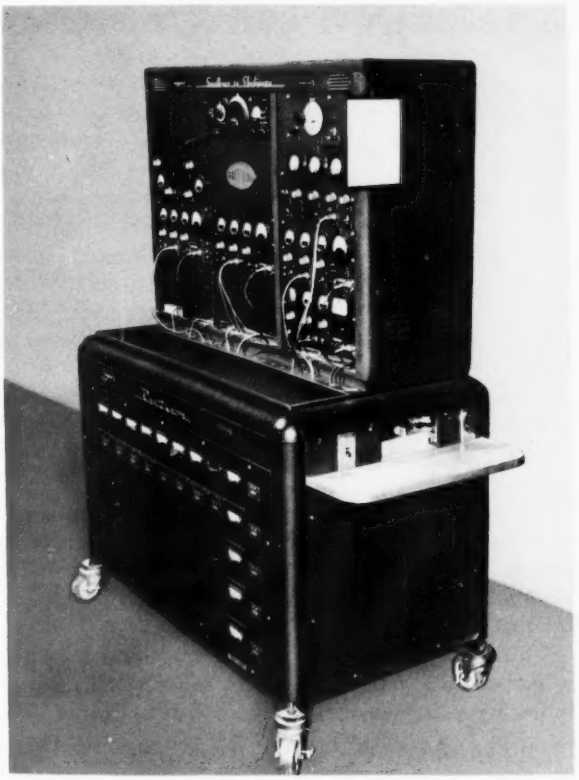
A resistance R_b', the extrinsic base resistance, exists between the base ohmic connection and the active base region. Power is lost in this resistance. Thus for high gain one desires to keep this quantity low. R_b' is particularly important at higher frequencies because it combines with the highly capacitive transistor input impedance to form a low pass filter. Like all resistance, it is low when the path through which current must flow is high in conductivity (high in impurity content and large in area).

Alpha decreases with frequency due to the relatively slow process of carrier flow in the base region. The carrier flow lags behind the input signal. At frequencies sufficiently high that the input signal is reversing before previously generated carriers reach the collector, these carriers become recalled, decreasing the collector current and therefore α. The frequency at which α is 3 db down from low frequency α is known as the frequency of alpha cutoff, $f_{\alpha b}$. If the base width is kept very thin, this cancelling effect is minimized and a transistor capable of high frequency gain results.

There are, of course, many more parameters one can define but this will not be attempted here. The important point to be derived from the concepts so far given is that all transistor parameters are a function of the following:

a. Concentrations of different kinds of impurities in given zones.
b. Distributions of these impurities within a zone and at boundaries of zones.
c. Extent of these zones.

Now, if one keeps in mind that each manufacturing technique implies certain limitations to how impurities can be distributed in solid material as a result of conditions existing during alloying, one will understand why some transistors are better at high frequency than others, why some are incapable of high voltage operation, why some lend themselves more readily than others to power applications, etc.



AUTOMATIC TRANSISTOR TESTER The machine, developed on a Signal Corps contract, is capable of automatically testing and classifying for nine transistor parameters.

The Grown Transistor

Single crystals of germanium are created by carefully controlling freezing conditions from a pool of the molten semiconductor. This operation of freezing out of the melt is known as "growing" and is common to all the techniques of transistor manufacture. In the case of the grown transistor, however, alloying constituents are added to the melt during the growth process, resulting in three zones of different chemical composition in the final single crystal. These zones are cut out of the crystal as tiny chips, each of which contains the required emitter, base, and collector. When soldered connections are made, the resulting structure is as shown in Figure 2. Note that the base connection is, of necessity, small and fragile.

A manufacturing disadvantage of this method is that an entire crystal must be grown to have just one thin slice of tri-layered material which may be cut up into potential transistor chips.

The rate-grown transistor is essentially a grown transistor which ingeniously eliminates this objection by taking advantage of the fact that all alloy-

ing additions freeze into the parent metal to a greater or lesser degree depending on the rate of freezing. By freezing alternately rapidly and slowly out of a melt containing alloying additions A and B, first A and then B can be made to predominate in the resulting crystal structure. Several dozen such alternating zones can thus be produced in one crystal. The structure is cut then into numerous slices of A-B-A zones, the slices diced, and the dice mounted similarly to the grown structure of Figure 2. Although this construction was announced several years ago, units have never been readily available, possibly because of fabrication difficulties.

A variation of the rate-growing process is to carry out the rate-controlled freezing in a single chip of semiconductor rather than in a whole crystal, the melt-back process. The end of a tiny rod of germanium or silicon is melted locally and then allowed to refreeze at a controlled rate. The resulting structure is again similar to that of Figure 2. Few units of this type have been generally available up to the time of this writing.

This whole family of grown transistors, because of the nature of the fabrication technique, has the following characteristics:

Basewidth: At the melting (freezing) point, impurities are very mobile and free to diffuse about and all alloy concentration gradients tend to become "ironed out." Thus transitions from one zone to another become gradual and indistinct. Under such conditions, a very thin base (in the order of a few ten-thousandths of an inch) tends to be wiped out by the diffusing-across and merging of the alloying impurities in the emitter and collector. Thus we see the first disadvantage of the grown transistor. W, the basewidth cannot practically be made thinner than a certain "floor" level. Accordingly an upper limit is placed upon $f_{\alpha b}$.

Collector Capacitance: Because of this gradual transition of impurities at the junctions, C_c is relatively small. This is a definite advantage of the grown transistor.

Extrinsic Base Resistance: This parameter is surprisingly high, running about 150-300 ohms in spite of the closeness of the base connection to the emitter. This is because of the nature of the base connection. Since the base itself is only in the order of 0.001" thick, a very fine wire must be bonded in locally, making a point of inherently high resistance.

Alpha: Alpha is generally satisfactory in grown units. However, it is on the low side for rate grown transistors where the emitter doping is not high. If the emitter doping were high, it would be more

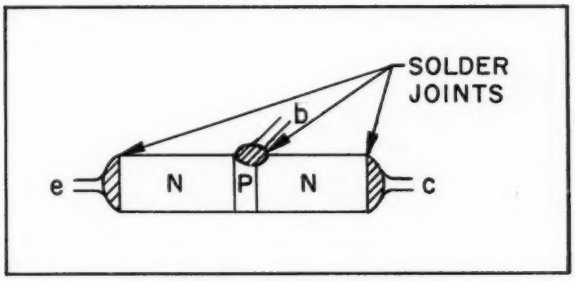


Figure 2. GROWN TRANSISTOR

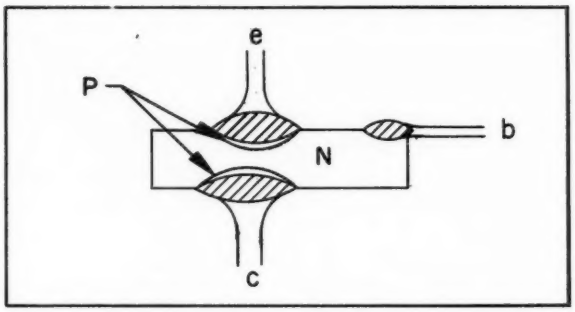


Figure 3a. FUSION-ALLOY TRANSISTOR (audio)

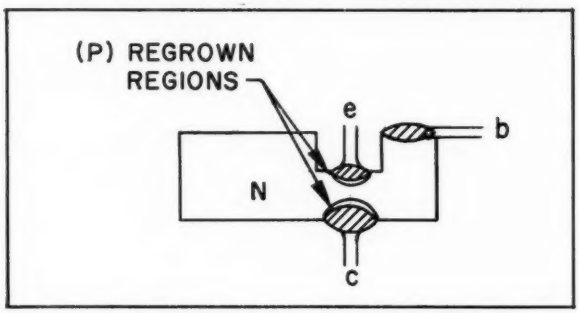


Figure 3b. FUSION-ALLOY TRANSISTOR (rf)

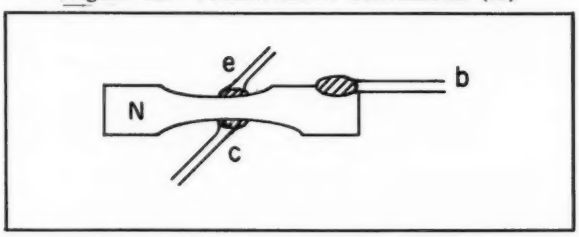


Figure 4. SURFACE BARRIER TRANSISTOR

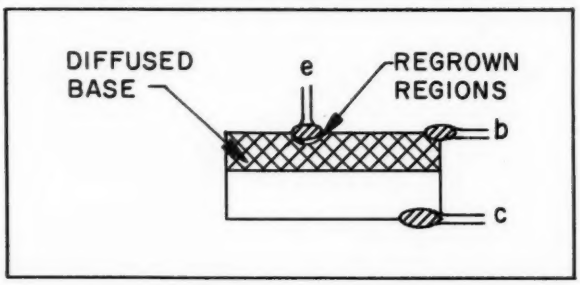


Figure 5. DIFFUSED-BASE TRANSISTOR

than difficult to overdope in alternating zones. Hence γ must be low and α also relatively low. An interesting consequence of rate growing is that emitter and collector are necessarily interchangeable. Thus the device is "symmetrical."

The Fusion-Alloy Transistor

Most transistors that have been made up to this time have been made by this technique. Raytheon's commercial product has been of this type up to the present.

Figure 3a shows the audio construction. Here a single crystal chip consisting of one conductivity type, N or P, is cut from a crystal of uniform resistivity. Dots of alloying metal are placed in contact with the chip, together with a non-doping ohmic base connection, and the entire assemblage placed in a furnace hot enough to melt the metal dot. This temperature may be as much as 400°C below the melting point of the semiconductor but the molten metal can nevertheless dissolve some of the semiconductor into itself at this temperature. During the course of this dissolving, the dots may be said in effect to penetrate. Upon removal from the furnace and freezing of the system, the semiconductor separates, within the previously fused dot, back into position again on the parent chip surface; that is, it grows back on in the process of crystal growth, since the dot can hold semiconductor in solution at elevated temperatures but not room temperature. The regrown region is different from the surrounding semiconductor in that it now contains a small alloy quantity of the alloying dot material. PNP or NPN single crystal structures can thus be achieved.

Because the fusion-alloy process takes place at the alloy melting point which is well below the melting point of the semiconductor alone, fusion, solution, and erosion may take place but there is only a negligible amount of impurity diffusion. Thus the transition (dielectric) zone is very narrow and the resulting capacitance is relatively high (about 3 times as high as that of the same area of grown junction).

ZONE REFINER The most powerful metal purifying tool known. Germanium is cleansed to one part of impurity per one billion parts of germanium.

High power transistors can be made by this technique by increasing chip and dot sizes and attaching the entire structure to a heat sink.

High frequency fusion-alloy transistors are made by the construction of Figure 3b where, by slotting or drilling, a chip is made locally very thin. Then W is automatically quite small. The dots are very tiny to keep down C_c. The large shoulders of semiconductor around the thinned region tend to keep R_b' low.

This unit is superior to the grown transistor in R_b' and $f_{\alpha b}$, and slightly higher for C_c. The first available units using this technique were the Raytheon CK 760 series, now the 2N111, 2N112, 2N113, 2N114.

The Surface Barrier Transistor

The Surface Barrier Transistor (Figure 4), is similar to the fusion-alloy high frequency unit in that a local thin spot is made for connection of emitter and collector. However, this is made chemically, not mechanically. The zones are etched out electrolytically and the etching controlled by a photocell circuit "looking" through the remaining web (germanium and silicon are transparent to infra-red light). This circuit automatically shuts

RELATIVE PERFORMANCE OF JUNCTION TRANSISTOR TYPES

Transistor Type	*Alpha*	$F_{\alpha b}$	*Punchthru* V_p	C_c	$R_{b'}$	*Power Dissipation*
GROWN						
regular	medium	fair	medium	good	fair	poor
rate grown	fair	fair	medium	good	fair	poor
melt back	medium	fair	medium	good	fair	poor
FUSION ALLOY						
audio	good	fair	good	fair	fair	good
r.f.	good	good	fair	good	good	good
power	good	poor	good	poor	very good	very good
SURFACE BARRIER	fair	very good	poor	good	fair	poor
DIFFUSED BASE	good	very good	very good	good	good	good

off the etching current when the web (W) is extremely thin (0.0001" to 0.0005"). Very thin metallic connections are then electroplated into place. There is no fusion or crystal growth. In fact there are no real P-zones created by alloying or doping. The "P" zones are actually localities having P-type centers as the result of reflected-in charges due to the metallic dots on the surface.

This type of construction has high $f\alpha_b$ and low C_c. Although the junctions are abrupt, the dots are very tiny — not exceeding 6 mils in diameter. It is therefore a good high frequency transistor when considered from the point of view alone of performance at frequencies above 10 Mc. It is very severely limited, however, by the narrow base width and the tiny dots, in V_c and dissipation. Voltage punch-through often occurs below 5 volts, and 15 mw of collector dissipation is a top limit. This kind of unit has been made successfully only in germanium. No successful silicon surface barrier units have been announced, probably because of high chemical activity on a silicon surface.

The Diffused Base Transistor

This diffused base principle was first proposed by Dr. Herman Statz of the Research Division early in 1953 and a transistor of this type was constructed later that year. It was independently invented by others around this time. It has many advantages from a theoretical point of view. However, since it does not have the same large scale production history as the previously described types, many of the advantages listed must be looked at as "paper" advantages until a retrospective picture can be drawn.

It differs from other transistor designs in that the base zone does not have a constant composition, but rather a varying impurity content such that impurity centers are perhaps one thousand times as numerous near the emitter as they are near the collector. These impurities take up their position in the crystal lattice and are in effect ionized so that an electric field exists in the base proportional to the impurity gradient. This is known as the principle of the built-in field.

This field is in such a direction and of such a polarity that when minority carriers are injected at the emitter they are accelerated across the base by the field. The net effect of this is to cause much better performance at high frequencies than would otherwise be the case.

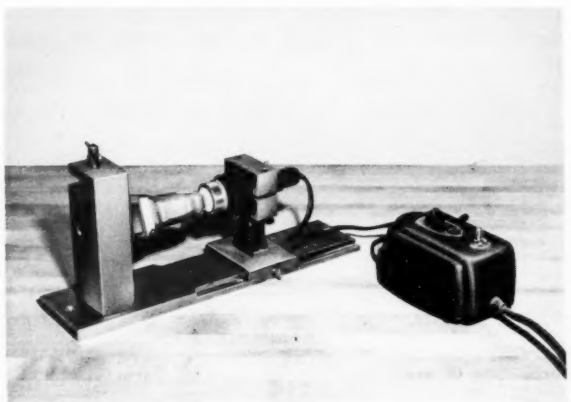
R_b', which is a function of the resistance between the base connection and the emitter connection, is substantially lower than in other types because of the high impurity content and high conductivity of the layer of semiconductor at the surface of the base. Because of the diffuse impurity gradient at the junction, collector capacitance, area for area, is lower here than for the fusion-alloy transistor, (although very small areas are difficult to achieve). Also because of the extremely high impurity concentration in the base adjacent to the emitter, it is very difficult for the transition region to punch-through this zone even at extremely high voltages.

Connections resemble those of the fused type. They may be relatively rugged and they may be designed for high wattage dissipations.

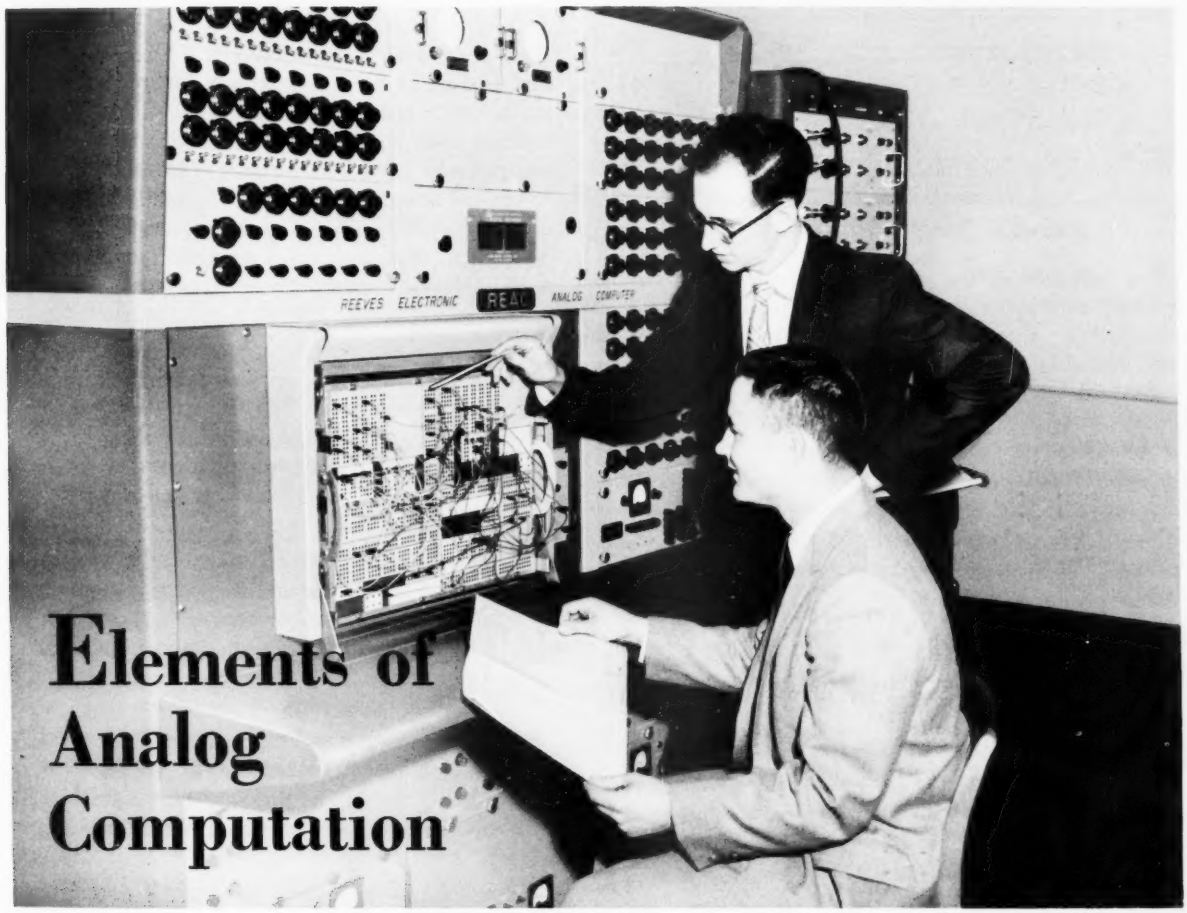
This design should remove many of the limitations imposed by the other types of construction for high frequency applications. First, the voltage limitations of punch-through and avalanche found in the grown surface barrier and alloy transistors should be negligible. The R_b' level is an order of magnitude better than the best of the other three types. $V_{sat.}$, the saturation voltage, tends, however, to be relatively high.

The diffused base transistor is the most promising of these transistor designs because most of the electrical parameters are simultaneously improved. It is interesting that the diffusion technique may be combined with other major techniques to result in transistors with combinations of properties. The literature mentions "grown diffused," "surface-barrier diffused," and "melt-back diffused."

To sum it up, each construction technique inevitably imposes limitations on the nature of the internal atom arrangements while at the same time endowing the structure with unique advantages. During the course of the next few years, some of these techniques will undoubtedly be abandoned, some will be retained and refined, and others, unthought of now, will appear on the scene. Of this we may be sure — transistors, unlike tubes, will always be made by some half dozen different techniques, each with its own disparagers and champions.



CRYSTAL ORIENTER This device utilizes etch pit reflections in order to determine major crystal direction.



Elements of Analog Computation

A. N. NICOL H. A. MILLER
Research Division

COMPUTERS are generally very simple devices. They consist of elements, which in themselves may be complex, that perform simple mathematical operations. Computers can perform complex operations if they are given a logical method of using their elements.

Analog computers contain elements that add, subtract, multiply, divide, integrate, generate functions and make decisions. These elements may be used to build a direct analog of a physical system, or an analog of the set of differential and algebraic equations that describe the physical system. The results are given as the values of the dependent variables and their derivatives, for all the desired values of the independent variable. For example, if the computer were used to solve for the velocity of an object vs. displacement, and the results were an exponential function, the computer would be capable of supplying a quantity which varied exponentially with respect to time; recognition of its exponential nature would be left to the operator and not supplied directly.

Electronic analog computers vary in design, and exist in both high speed or repetitive computers and low speed or "real-time" types. In all electronic analog computers the main elements are high gain dc amplifiers. With the use of feedback, these amplifiers can be used to add, subtract, multiply by constants and integrate with respect to time. In low speed computers, servos are used to multiply and divide by variables, generate functions, and convert from polar to rectangular coordinates and vice versa. Diodes are used to generate functions. Relays are used as decision elements.

Among the many problems studied on analog computers by Raytheon personnel, one which is particularly illustrative of several techniques is the study of the large signal behavior of certain crossfield microwave tubes by W. C. Brown, Power Tube Operations. The aim of this study is to improve the design and increase the efficiency of such devices by obtaining a better understanding of the principles involved.

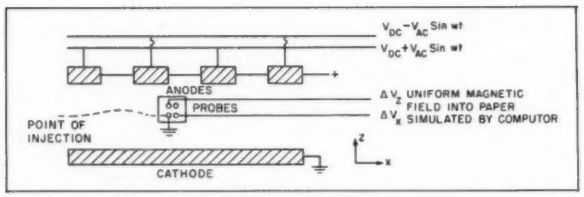


Figure 1. FUNCTION GENERATOR

The first part of the program was a study of the electron trajectories in an idealized linear travelling wave device. The electrons were emitted from an ideal gun and passed between a series of anodes (vanes) and a long cathode, as shown in Figure 1. The potential between each vane and the cathode can be described as a sinusoidal voltage which is a function of time superimposed on a dc potential. Each vane is 180° out of phase with its neighbor, and all vanes have equal amplitudes of sinusoidal voltage. The voltage at any point of the electron's travel is:

$$V = f(x,z)\ (V_{DC} + V_{AC}\ \sin\ (wt + u(x)\pi/2))$$

This voltage was generated on a function generator which simulated the physical construction of the device being studied.

The equations of motion of the electron are the simultaneous differential equations:

$$\frac{d^2x}{dt^2} - \frac{e}{m} B \frac{dz}{dt} - \frac{e}{m} E_x = 0 \qquad [1]$$

$$\frac{d^2z}{dt^2} + \frac{e}{m} B \frac{dx}{dt} - \frac{e}{m} E_z = 0 \qquad [2]$$

where E_x = potential gradient along x axis
E_z = potential gradient along z axis
B = magnetic field
e/m = charge-mass ratio of an electron

In the specially constructed function generator, the electrodes rest on resistive paper which acts as a two dimensional potential divider. Two of the probes measure the change in potential, $\triangle V_x$ and $\triangle V_z$, from the grounded probe. The probe separation is constant so that the measurement is proportional to $\frac{\triangle V_x}{\triangle x}$ or $\frac{\triangle V_z}{\triangle z}$ which are, respectively, very nearly E_x, E_z.

The analog computer, Figure 2, is set up to solve

$$\ddot{X} = \frac{e}{m} B \dot{Z} + \frac{e}{m} E_x \qquad [3]$$

$$\ddot{Z} = -\frac{e}{m} B \dot{X} + \frac{e}{m} E_z \qquad [4]$$

In such a setup, if the input to Integrator 1 is the right hand side of Equation 3, the output is $-\dot{X}$ and is used as an input to Integrator 2 giving X as an output. Integrator 3 supplies $-\dot{Z}$ in the same fashion with Z the output of Integrator 4. In this setup it was necessary to have $\dot{Z}$ to solve for X and to have $\dot{X}$ to solve for Z. The procedure is to assume $\dot{Z}$ is available to solve $\ddot{X}$ and use it as if it did exist. Then $\dot{X}$ is used to solve $\ddot{Z}$ and the connections are made. Now $\dot{Z}$ does exist just as assumed. This procedure is extremely useful in solving simultaneous equations.

Second order differential equations require two boundary conditions. The IC (initial condition) on Integrator 1 sets the initial velocity in the X direction and the IC on Integrator 2 sets the initial X displacement. The IC's on Integrators 3 and 4 do the same for the Z axis.

The servos, which are a part of the function generator, drive the probes as the computer solves the equations. As the probes move, they continually supply new information to the computer to calculate the effects of the changing electrical field upon the simulated electrons.

In this problem the time scale has been greatly expanded. The calculation of a trajectory takes several minutes. In the physical system, the actual time involved would be measured in millimicroseconds.

A set of electron trajectories in a linear device with 4 vanes is shown in Figure 3 as plotted by the computer. The optimum time of entrance into the fields occurs when the sinusoidal voltage component on the odd numbered vanes is zero and increasing. The angle of phase lead of the electron is measured from this part of the waveform. A 40° phase lead indicates that the sinusoidal potential on the odd numbered vane is equal to $V_{AC} \sin (360° - 40°)$ at the time the electron enters the fields.

An electron is useful if it reaches one of the vanes.

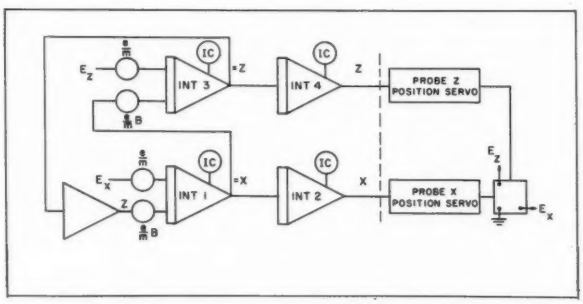


Figure 2. COMPUTER DIAGRAM

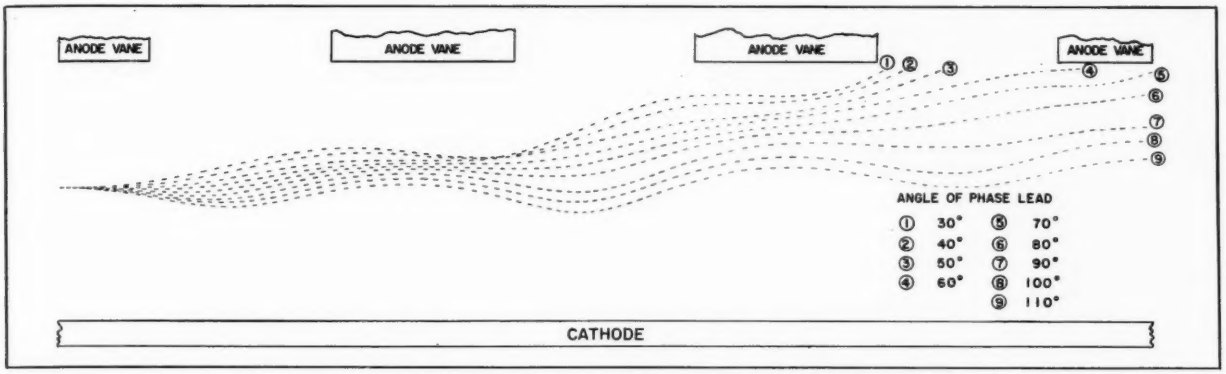


Figure 3 Electron trajectories in a linear device with four vanes.

In these trajectories, electrons 1, 2 and 3 will reach vane 4. Electron 4 might reach it. The other electrons will not.

In many computer setups, it soon becomes apparent that there is a need to consider a more realistic problem; parameters and equations are easily modified on electronic analog computers. The problem was extended to allow variations in the amplitude and relative phase of the sinusoidal voltage on each vane, thus changing the operating conditions of the device that was being simulated. Another addition that could be made would be to simulate the ejection of electrons from a real gun. In the present setup all electrons enter the crossed fields from a point source and are parallel to the axis of the device. In an actual device there would be electrons emitted at various angles with the axis.

The next step taken in changing the problem was to simulate a device based on a circular arrangement of vanes, as in a magnetron or platinotron. The function generator was altered to represent such a device. The electrons are now emitted by a central cathode and their behavior studied, starting at a point when they are circling the cathode. The relative phase and amplitude of the sinusoidal voltage are variable. This is the program at present.

In this program several aspects of analog computing are shown. An event which takes place in a very short time is simulated in a much greater time interval. Many times the opposite is done. Secondly, an analog computer may be tied in with external devices. This often allows equipment to be tested and evaluated when only part of the complete system is available. In utilizing an analog computer, it is necessary to first define the problem and describe it in a rigorous manner. A method of calculation must be determined; that is, in the example given, should one compute efficiency, power, gain, or should one plot trajectories? The equations must be placed on the computer, a systematic variation of conditions made, and finally the resulting plots interpreted. The problem being studied is refined and amplified; new avenues of study are suggested. The last aspect is perhaps the most important. The net result is a better understanding of the problem as well as answers to the original questions.

RESEARCH DIVISION
ANALOG COMPUTER FACILITY

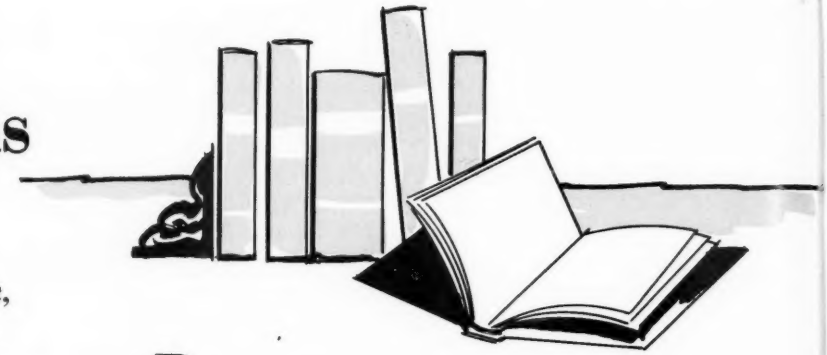
An analog computer was installed in the Research Division in March 1957. The computer has been purchased for company wide use and is available to all technical and scientific personnel of Raytheon. The Applied Electronics Group of the Research Division provides service and assistance in operating the computer. Interested persons should contact A. Norman Nicol (Ext. 2891) for further details or to schedule time on the computer. A short introductory manual on analog computing will soon be available to all who desire a copy.

The analog computer facility at the Research Division consists of:

- 40 Operational amplifiers normally used as
  - 12 Integrators (may be converted to Summers or Inverters)
  - 12 Summers (not easily converted)
  - 16 Inverters (may be converted to Summers or Integrators)
- 54 Scale factor potentiometers
- 4 Servos as follows:
  - 2 Multiplying Servos (5 potentiometers)
  - 2 Resolving and multiplying Servos (2 sin-cos, 3 potentiometers)
- 10 Function generation channels consisting of
  - 2 Diode Function Generator channels
  - 2 Channels of loaded potentiometer function generators on each servo
- 10 Free diodes
- 2 Function relays
- 3 Read out devices consisting of
  - 1 Digital voltmeter accurate to 0.01 volts
  - 1 Six channel strip recorder
  - 1 Two axis plotter

These computing elements are interconnected on a detachable patch board. It is also possible to use external devices in conjunction with the computer so that parts of a system may be tested independently of the rest of the system.

Technical Publications



W. W. DRAKE, JR.
Office of the Vice President, Engineering and Research

A man is known by his work. Nowhere is this truism more applicable than in creative science and engineering. Such work cannot in general be understood and recognized till it is reduced to writing and broadly disseminated. It is, therefore, to the interest of each member of our large research and engineering staff to publish his contributions as broadly as possible. The individual personal recognition resulting from such activity reflects both on the author and also on the institution of which he is a part.

Ivan A. Getting

Vice President, Engineering and Research

RECOGNIZING the need for publication and its importance to the communication of ideas, Mr. Charles F. Adams in a policy statement issued in 1952, established policies designed to encourage and promote technical publication. Dr. Ivan A. Getting was delegated the responsibility as Vice President, Engineering and Research, to establish and promote a policy of encouragement to all persons employed in a technical capacity to prepare papers for publication. This policy was further broadened in 1954 to include the preparation of technical books.

Publication in the broadest sense includes the giving of talks. It is general policy of the Company to pay all of the usual allowable expenses involved in giving the talks, such as travel, stenographic and photographic assistance. If a fee or honorarium is offered from an outside agency in which travel expense is specifically covered by the fee or honorarium, travel expenses are not considered reimbursable by the Company. Otherwise, the entire honorarium is retained by the author. The same basic policy holds in the case of honoraria in connection with papers published in trade journals. Expenses involved in the preparation of such papers are borne by the Company. Remuneration for the papers when offered by the publishers of the trade journals is retained by the author.

In the case of books, royalties, which are dependent on the type of book, go to the author. If the work is a joint effort of several engineers written specifically for the Company, as part of the technical responsibilities of the authors, the royalties accrue to the Company. The Operations may, where appropriate, authorize stenographic, art, and photographic assistance in the preparation of the book. Similarly, time devoted to the preparation of the book may be borne in whole or in part by the Operations. At the present time there are several books in preparation in the following fields: transistors, microwave tubes, microwave techniques, plastics, microwave heating, and applied mathematics.

Of necessity a procedure for the clearance of

papers and talks has been established. The procedure for review is designed to maintain at a high level the quality of the material submitted. There is also the need for review from the standpoint of the Company's patent position, possibilities of commercial application, military security classification, and timeliness. Papers, talks, and book manuscripts are reviewed by a Technical Publications Panel with these factors in mind. The Panel consists of representatives of the major engineering and research areas of the Company. Before publication specific approval of this Panel must be obtained for each paper or talk, and before republication of the same paper or talk.

This latter provision is made in view of possible exceptions made to initial publication which might not be allowable in subsequent publication. A paper or talk is submitted to the Panel through the divisional Panel representative. Since the writing of a book normally involves a great deal of time and the signing of a contract with a publisher, a potential author of a book is asked to submit his proposal to the Panel for approval.

To provide for greater communication within Raytheon, there have been issued from time to time Raytheon Technical Reports. These reports were established as a means for wider distribution of special studies, surveys of specific technical areas, or reports of investigations made which might prove of particular value and interest to other departments of Raytheon. Occasionally these reports have proved useful in acquainting universities and other industrial laboratories with a particular program.

Should you have participated in writing, or have written a report, on a program or project which has application and interest to more than your own particular group, and might be suitable to be published as a Technical Report, you are urged to bring the report to the attention of your Panel representative.

It is hoped that this brief review may be helpful and serve to encourage those who have deferred publication, because of the press of current responsibilities, to consider writing for the benefit of others.

TECHNICAL PUBLICATIONS
PANEL MEMBERS

I. A. Getting, Vice President, Engineering and Research, Chairman
G. G. Barker, Public Relations Department
H. R. Boyd, Research Division
W. C. Brown, Microwave and Power Tube Operations
R. P. Curtis, Commercial Equipment Division
W. W. Drake, Jr., Panel Secretary
E. J. Gorn, Law Department
T. A. O. Gross, Missile Systems Division
W. M. Hall, Government Equipment Division
T. J. Kelly, International Operations
J. S. Kendrick, Santa Barbara Laboratory
P. T. Weeks, Receiving & Cathode Ray Tube Operations

Inventions

Congratulations to the following persons for their valuable contributions to Raytheon's portfolio of inventions:

Name	*Field of Invention*
Joseph Apelbaum	Impregnated Thorium Cathode
T. Baker P. Minot A. Slater	Ferrite Modulators
Edward Dench	Backward Wave Oscillator
Henry Eisler & Winston Harvey	Variable Speed Drive
Robert Rapuano	Duplexing System Modulating Circuits
Homer Holzcrafe Harmon Keeling Harold Rosen Robert White	Autoplexer
Paul Miller	Antenna System
Harold Rosen	Scanning System Ferrite Modulator Duplexer
Louis Schall & Donald Winsor	Cathode Filter
Howard Scharfman	Broadband Thruplexer

Publications & Papers

"A Practical Design Theory for Minimization of Vibration Noise in Grid-Controlled Vacuum Tubes"

GERALD H. GROSS
I.R.E. National Convention

New York, New York, March, 1957

Abstract: Theory shows vibration noise minimization is achievable through electrical and/or mechanical design. It is shown, however, that determination of requisite conditions by operations on the plate current equation is invalidated in the island effect region, commonly the region of receiving tube design. This results from a substitution into the plate current equation of geometric functions defining the electrical parameter μ which are themselves inapplicable in this region.

The practical design theory presented here is based upon empirical determination of the μ function and consequent application of its variance with vibration to either: (1) reduce its vibration effect to zero, or (2) use it to cancel other vibration effects.

"Biased Chokes for Improved Swinging Choke Action"

T. A. WEIL
IRE Meeting

Dayton, Ohio, May 13, 1957

Abstract: The new circuit described permits a swinging choke for DC supplies to be made smaller by making the full (bidirectional) flux swing of the core material available for use; therefore, size and weight are saved.

This advantage is most pronounced in the design of a wide-range swinging choke, since in this type of design the air gap tends to be small and the retentivity of the core material prevents the utilization of even as much flux swing as in normal filter choke design.

Since this circuit makes practical the design and use of swinging chokes working down to one or two per cent of full load current, the bleeder current can be reduced, and power supply efficiency is, therefore, increased, compared to standard practice.

Various other applications of biased chokes are described.

"Pressure Induced Changes in the Optical Absorption of Ge, Si, Te"

L. J. NEURINGER
American Physical Society Philadelphia Meeting

Philadelphia, March 21-23, 1957

Abstract: Measurements of the intrinsic optical absorption coefficient have been made on thin single crystal specimens in the pressure range 1-2,000 atmospheres. The most recent version of the Bardeen, Blatt, Hall theory has been used to determine the pressure coefficient of the (111) conduction band minimum in germanium by extrapolation to zero absorption coefficient. This value is 8.1×10^{-6} ev/atmosphere with the value from the (000) minimum being about 50 per cent larger. In silicon the pressure coefficient is -1.8×10^{-6} ev/atmosphere, in agreement with Warschauer, Paul and Brooks. Both $E_g \perp$ and $E_g \parallel$ in tellurium decrease with increasing pressure. There is an indication that initially $E_g \perp$ decreases more rapidly with pressure than $E_g \parallel$, in accord with the calculations of Reitz. These pressure coefficients then permit a direct calculation of the lattice dilatation effect of temperature.

"Ferromagnetic Resonance in Polycrystalline $Ni\ Fe_{2-t}\ Al_t\ O_4$"

J. R. ZEENDER AND E. SCHLOEMANN
American Physical Society Meeting

Washington, D. C., April 25-27, 1957

Abstract: Measurements were made at X-band for t between 0.6 and 1.0. Near the magnetic compensation point, the resonance line is very wide and has a shape similar to the one observed by McGuire in $Li_{0.5}\ Fe_{1.25}\ Cr_{1.25}\ O_4$. Measurements between —70°C and 360°C made on a sample with t=0.65 quenched from 1200°C gave the following results: At room temperature the line shows a main absorption peak and shoulders on each side. At higher temperatures, the line is narrower, the shoulders are less pronounced and finally disappear. At lower temperatures, the low field shoulder becomes the predominant adsorption peak, and two shoulders are observed on the high field side. Similar results are obtained for different compositions and after quenching from different temperatures. The line shape is interpreted on the basis of the theory given in the preceding abstract. Reasonably good agreement is found between measured and calculated line shapes, if it is assumed that the first order cubic anisotropy constant is negative and that all higher order anistropy constants are zero. The anisotropy fields $2\ K_1\ /M_s$ determined in this way are in the range of 800-1700 Oersteds.

"Positive Ion Bombardment of Germanium and Silicon"

SUMNER P. WOLSKY
M.I.T. Conference on Physical Electronics

Cambridge, Mass., March 21-23, 1957

Abstract: The vacuum microbalance has been used to study the sputtering of germanium and silicon by argon ions. The samples were prepared in vacua of $\sim 10^{-9}$ mm prior to bombardment. Ion energies of 50-900 ev and pressures of 10^{-3} to 10^{-4} mm were used. The rate of sputtering at corresponding ion energies was found to be greater for germanium than silicon. The variation of sputtering with ion energy also is quite different for germanium and silicon.

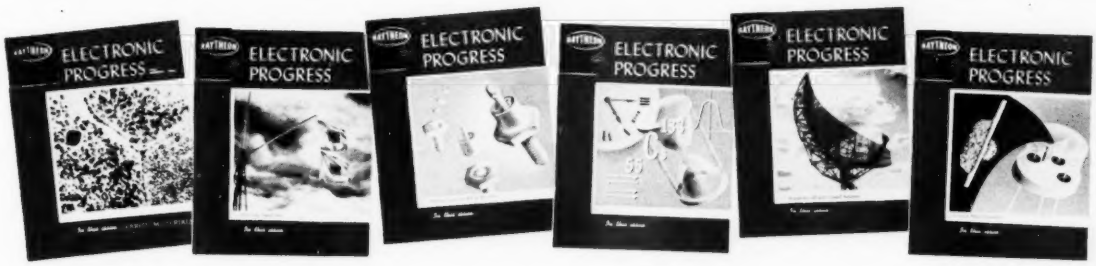
The microbalance technique appears to offer an excellent means for the determination of critical voltages necessary for sputtering and for study of the sputtering process itself.

"Evaporative-Gravity Cooling for Electronic Equipment"

M. MARK, M. STEPHENSON AND C. GOLTSOS
National Convention on Military Electronics

Washington, D. C., June 17, 18, 19, 1957

Abstract: In many aircraft the heat sink available for equipment cooling is ram or engine bleed air. Optimum use of this air to minimize the amount required is usually a design objective. For the case of electronic components and packages, either for thermal or electrical reasons, the cooling air is often not ducted directly over the components but is passed through a heat exchanger. Consequently, the thermal path between the heat exchanger and components must be of low impedance to result in efficient heat transfer. The high heat transfer coefficient obtained as a liquid boils and condenses may be utilized to effectively reduce the temperature drop between the electronic components and the heat exchanger.



In the Way of a Request ....

This issue of *Electronic Progress* marks the completion of our first year. It is time to assess not only what we have already achieved, but also what we hope to accomplish in future issues.

Somewhat over a year ago when plans were first being made, a basic position was taken which to a large degree established the policy framework of the magazine. That there should be a periodical for technical personnel had been decided, but what type of magazine was it to be?

For a moment let us examine the organization which was to receive and judge this embryonic publication. At Raytheon, some twenty-two hundred engineers pour their energies and talents into projects ranging from microwave tubes to semiconductor devices, from electronic welding to multipurpose, complex weapons systems. But this isn't the complete story.

Within any one of these areas, the word "engineer" itself may encompass the gamut from research scientist through development, production, applications, and field engineer. Electrical, mechanical, aeronautical, and chemical engineers are all employed here, as well as mathematicians, chemists, and physicists. Finally, this picture of a vast group with widely diversified interests is further complicated by a consideration of the geographical areas where Raytheon plants, laboratories, and field stations are located: Oxnard and Santa Barbara, California; White Sands, New Mexico; Bristol, Tennessee; Hooksett, New Hampshire; and the Boston area — a list which is not all-inclusive.

Although obviously the basic purpose of the magazine was to provide a channel of communication between these varied groups, the diversity of Raytheon professional personnel demonstrated that communication of detailed technical information *per se* was by and large self defeating. The editorial board has therefore attempted instead a broad coverage of technical problems and of group endeavors to solve them, leaving it to the reader to associate these with his own work and to follow up in obtaining more detailed information where desired.

We also found that in a broader sense communication with and among Raytheon technical personnel involved more than the strictly technical. As a result, we have tried, while still maintaining our technical orientation, to provide articles on Raytheon's general activities and policies in the belief that this knowledge is both healthful and useful to a professional readership. This appeared particularly desirable in view of the growing percentage of activity away from the Waltham area.

The second year of publication is now facing us. In a real sense *Electronic Progress* is both published for and dependent on its readers. The worth of a magazine of this type can be increased to its optimum only if it is being fully used. Since such use is a two-way street, the editors wish to encourage voluntary submission of articles for consideration as one of the major ways to increase the usefulness of the magazine. If you do have an article that you think might be of general interest, it should be submitted to the associate editor representing your division. In addition, the editorial group needs to know your evaluation of what has already been published and also what future coverage you feel would be of value.

As a way of implementing all of this, we are enclosing a questionnaire. It has been prepared for ease of filling out. However, we strongly urge that you do not take the easy way. The checked blanks will furnish us with much that we need to know, but the really valuable information will be in the comments of all who take the time to expand on their views, by separate sheets if necessary.

Perhaps a target for your comments might be in order over and above the past issues. Tentative planning for the next year includes technical coverage in line with that of the first year. We also hope to explore some new areas which should be of interest to the technical personnel. Among these will be patents, engineering policies, and descriptive articles on the various plants and affiliates which contribute to the entity called Raytheon. Within the allowances of proprietary interests, we hope to demonstrate some of the manufacturing skills which have contributed to Raytheon's pre-eminence in electronics. Then, we would like to trace a Raytheon product into the field to show the part played by field engineering personnel. Obviously, all of this cannot be done in the available space even over a year. What is done should be guided to a large extent by what interests and helps you.

Printed in U.S.A.

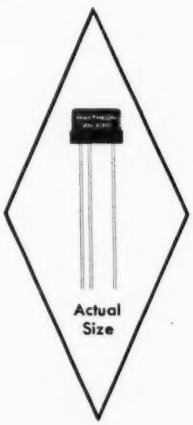
NEW PNP SILICON TRANSISTORS

by RAYTHEON

in the approved JETEC 30 package — now available

- designed for automation
- 0.200″ pin circle dia. — ideal for printed circuits
- Raytheon-perfected Fusion-Alloy process means extreme reliability — less than one open in 800,000 hours†
- temperature range: minus 65°C to plus 160°C
- low cutoff current
- welded — hermetically sealed
- > 2N329 — *new high Beta type*
- > 2N330 — *lowest noise factor of any make silicon transistor*

†based on 20,000,000 hours of Raytheon *fusion-alloy* transistor life tests



RAYTHEON NEW HIGH TEMPERATURE SILICON TRANSISTORS

Type	Replaces	Reverse Current at—20V* Collector μA	Reverse Current at—20V* Emitter μA	Beta	Base Resistance ohms	Collector Resistance kilohms	Noise Factor db(max.)	Collector Capacity μμf	Alpha Freq. Cutoff KC
2N327	CK790	0.005	0.005	14	1200	500	30	35	200
2N328	CK791	0.005	0.005	25	1400	500	30	35	350
2N329		0.005	0.005	50	1500	500	30	35	500
2N330	CK793	0.005	0.005	18	1300	500	15	35	250

*at 25°C

RAYTHEON SILICON TRANSISTOR TESTS INCLUDE:

- *Life* — conducted at 135°C and 50 mW dissipation
- *Temperature Cycling* — 116°C (Steam at 10 lbs. gauge) and minus 60°C
- *Temperature Aging* — 100 hours at 160°C
- *Acceleration* — 5000 G centrifuge
- *Shock* — 500 G

RAYTHEON®

SEMICONDUCTOR DIVISION

Silicon and Germanium Diodes and Transistors • Silicon Rectifiers

NEWTON, MASS.: 150 California St. • DEcatur 2-7177
NEW YORK: 589 Fifth Ave. • PLaza 9-3900
CHICAGO: 9501 Grand Ave., Franklin Park • TUxedo 9-5400
LOS ANGELES: 5236 Santa Monica Blvd. • NOrmandy 5-4221